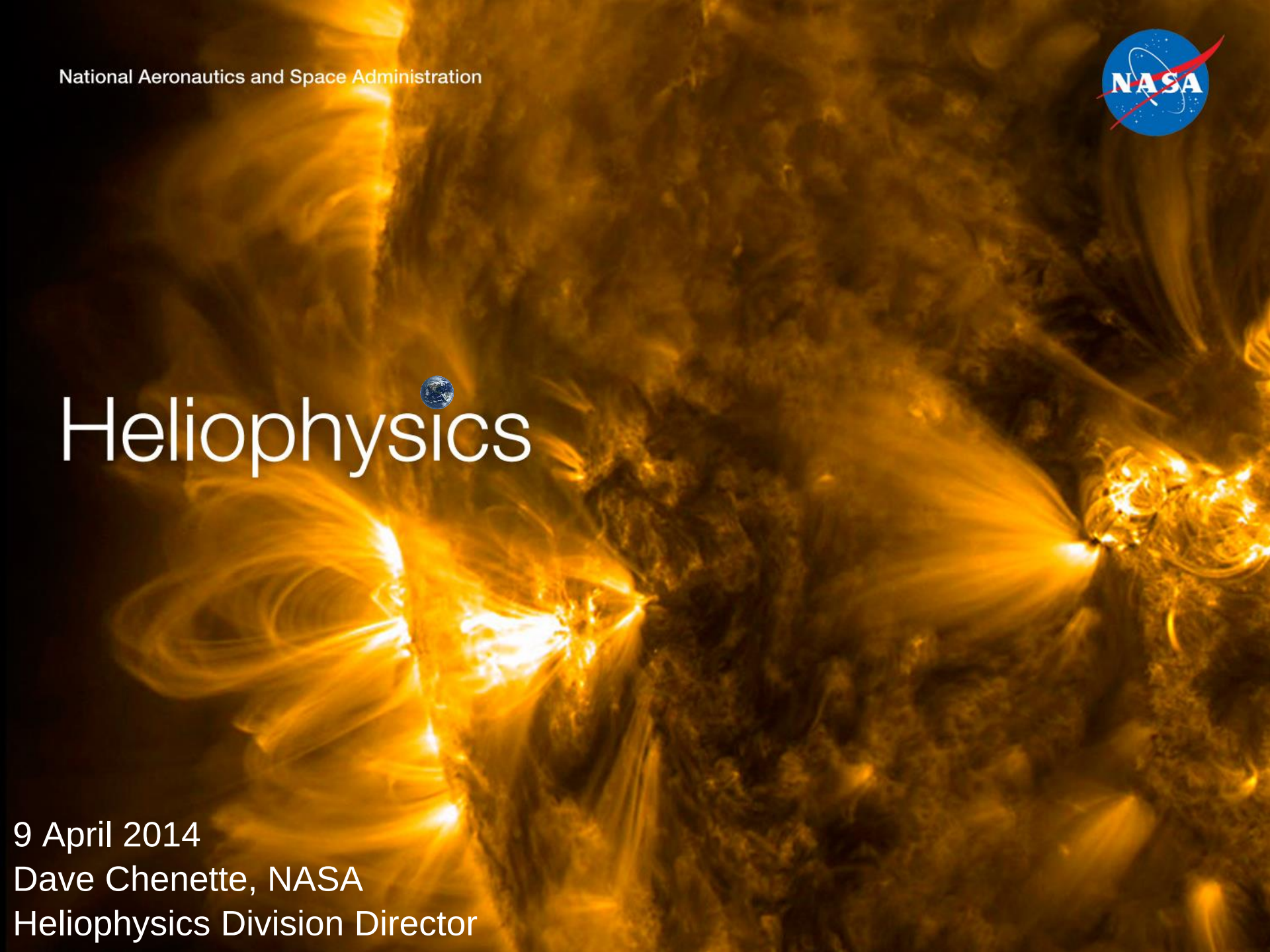
National Aeronautics and Space Administration



Heliophysics

9 April 2014

Dave Chenette, NASA
Heliophysics Division Director

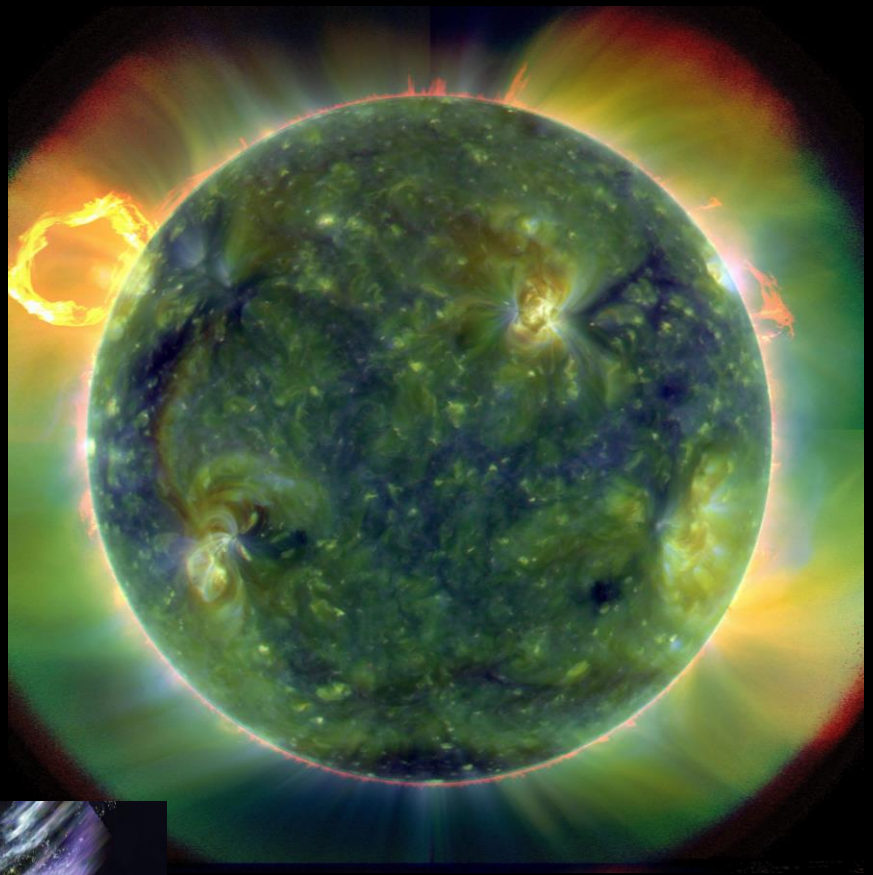
NASA Heliophysics Science Objective

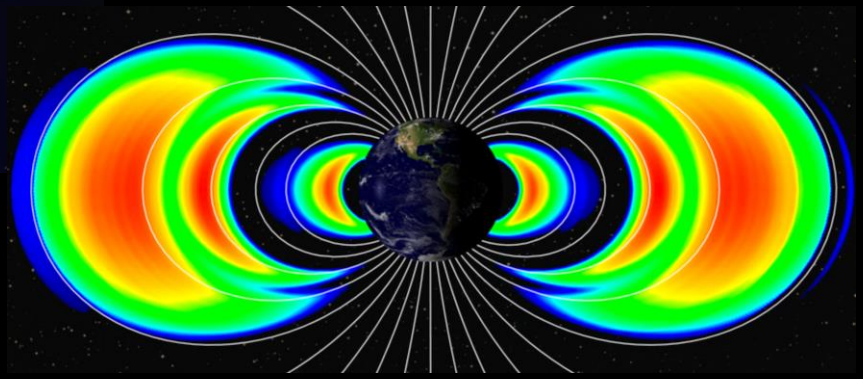
Understand the Sun and its interactions with the Earth, the Solar System, and the Galaxy.

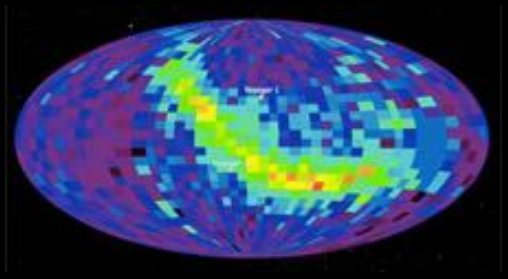
Solve the Fundamental Mysteries of Heliophysics

Understand the Nature of our Home in Space

Build the Knowledge to Forecast Space Weather Throughout the Heliosphere

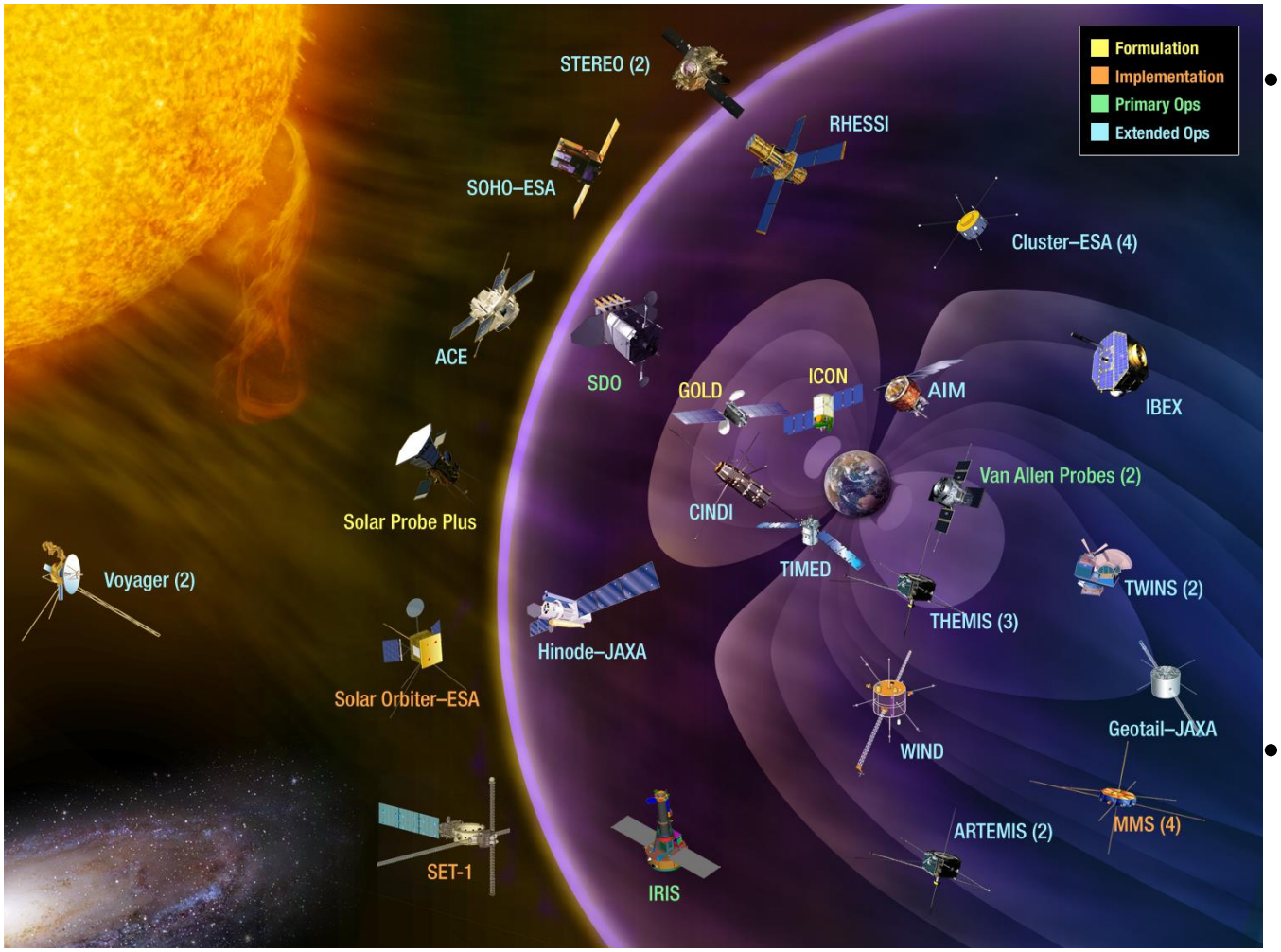






Heliophysics System Observatory

A coordinated and complementary fleet of spacecraft to understand the Sun and its interactions with Earth and the solar system



- **Heliophysics has 18 operating missions (on 29 spacecraft):** Voyager, Geotail, Wind, SOHO, ACE, Cluster, TIMED, RHESSI, TWINS, Hinode, STEREO, THEMIS/ARTEMIS, AIM, CINDI, IBEX, SDO, Van Allen Probes, IRIS

  (Missions in red contribute to operational Space Weather.)

- **6 missions are in development:** SET, MMS, SOC, SPP, ICON, and GOLD

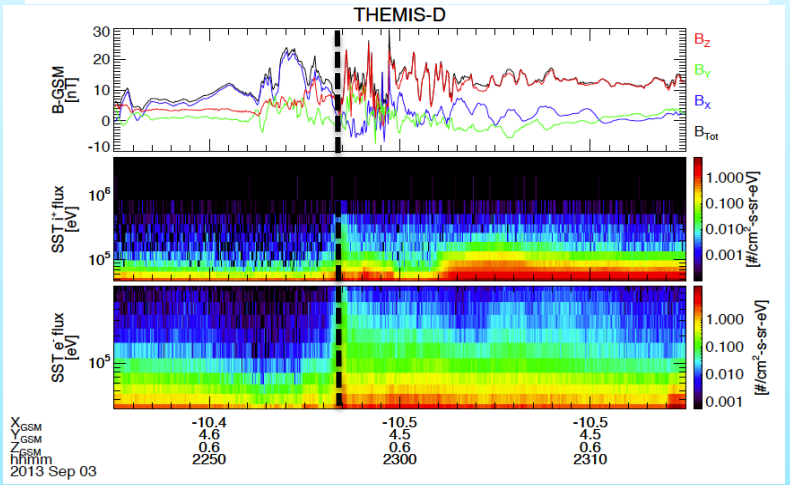
$5.5B total investment in Heliophysics space assets (excluding launch costs)
$68M annual operating budget

Tracing Energy Flows Through the Magnetosphere

Particle injections from the plasma sheet to the inner magnetosphere: Coordinated studies with THEMIS, Van Allen Probes, and geosynchronous satellites (Gkioulidou / Malaspina)

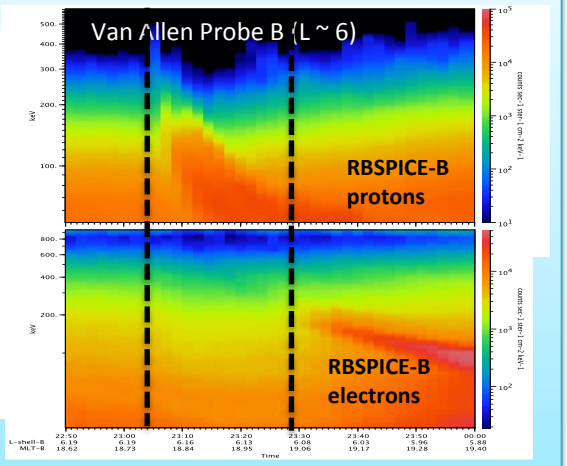
Outer magnetosphere: THEMIS D: ~10 R_E

- First observed dispersionless injection ~22:57 UT both in ions and electrons up to s ~800 keV
- Clear dipolarization of the magnetic field



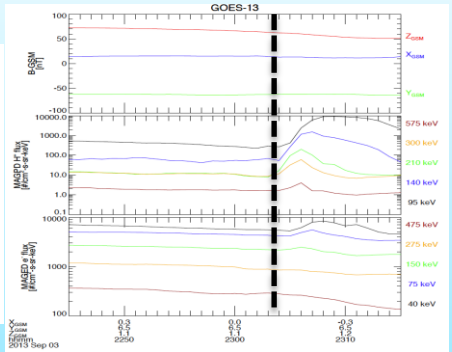
Inner magnetosphere: Van Allen Probe B: L ~ 6

- Observed dispersed in energy injection
- at ~ 23:04 UT for protons (dusk-ward drift) up to ~ 500 keV
- at ~ 23:28 UT for electrons which have drifted around the earth up to ~200 keV (dawn-ward drift)

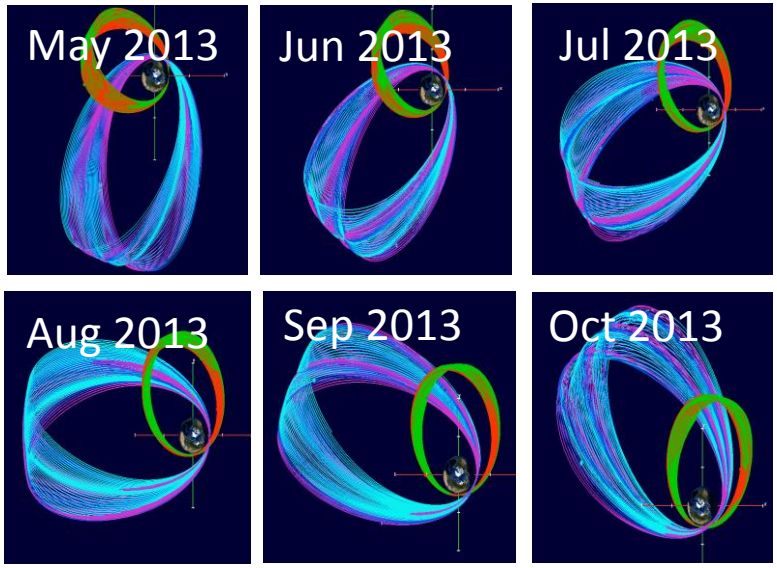


Geosynchronous: GOES 13 L = 6.6

- Observed almost simultaneously with VAP B the dispersed proton injection up ~300 keV
- No magnetic field dipolarization signature



Orbits for additional collaborations

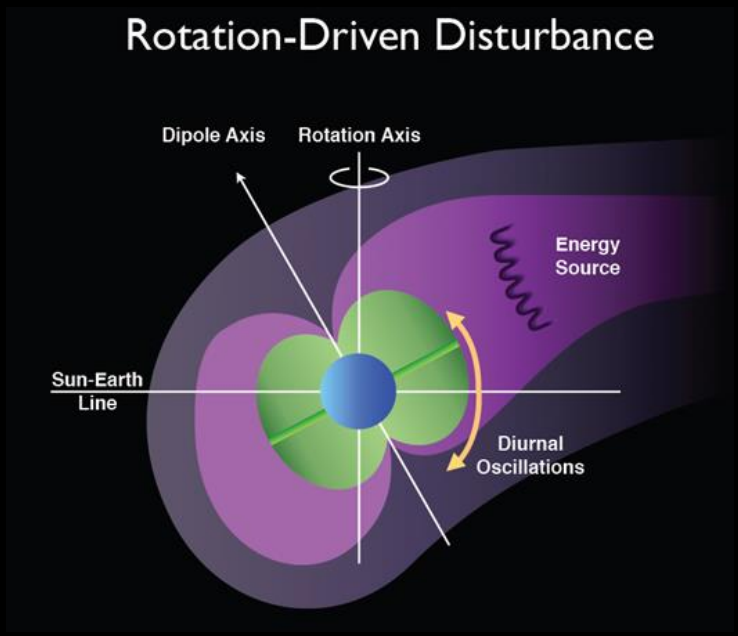


Earth's Rotation Unexpectedly Causes "Zebra Stripes" in the Inner Electron Radiation Belt

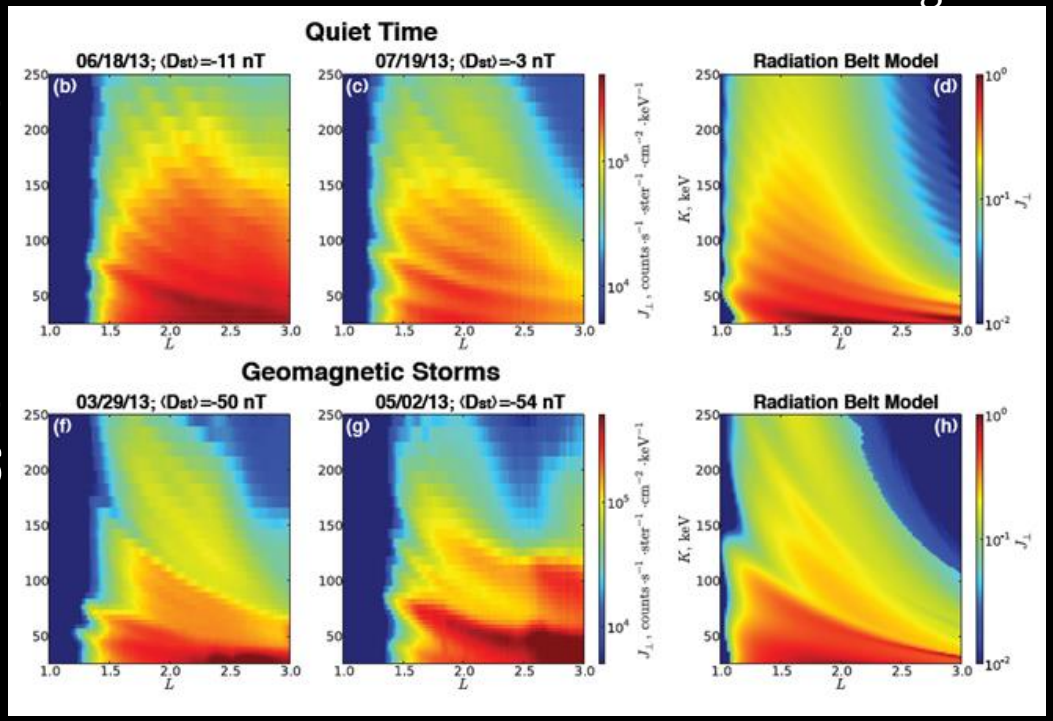
The Van Allen Probes RBSPICE instrument has discovered stripe-like patterns, termed "Zebra Stripes" in the inner portions of Earth's electron radiation belt.

Earth's rotation causes a very weak electric field whose effect builds up strongly over time due to quasi-resonance with drifting electrons.

The stripe pattern is caused by a stretching and folding of electron clouds, much like taffy is stretched and folded in a candy machine.

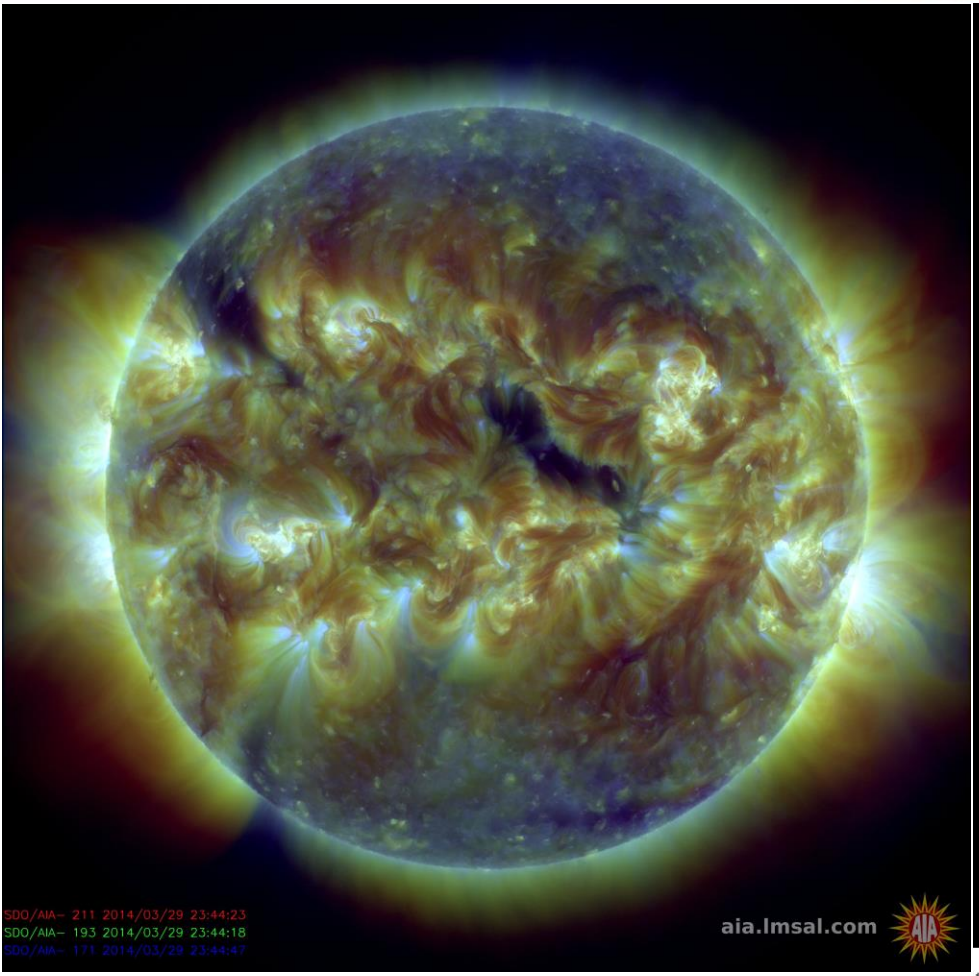


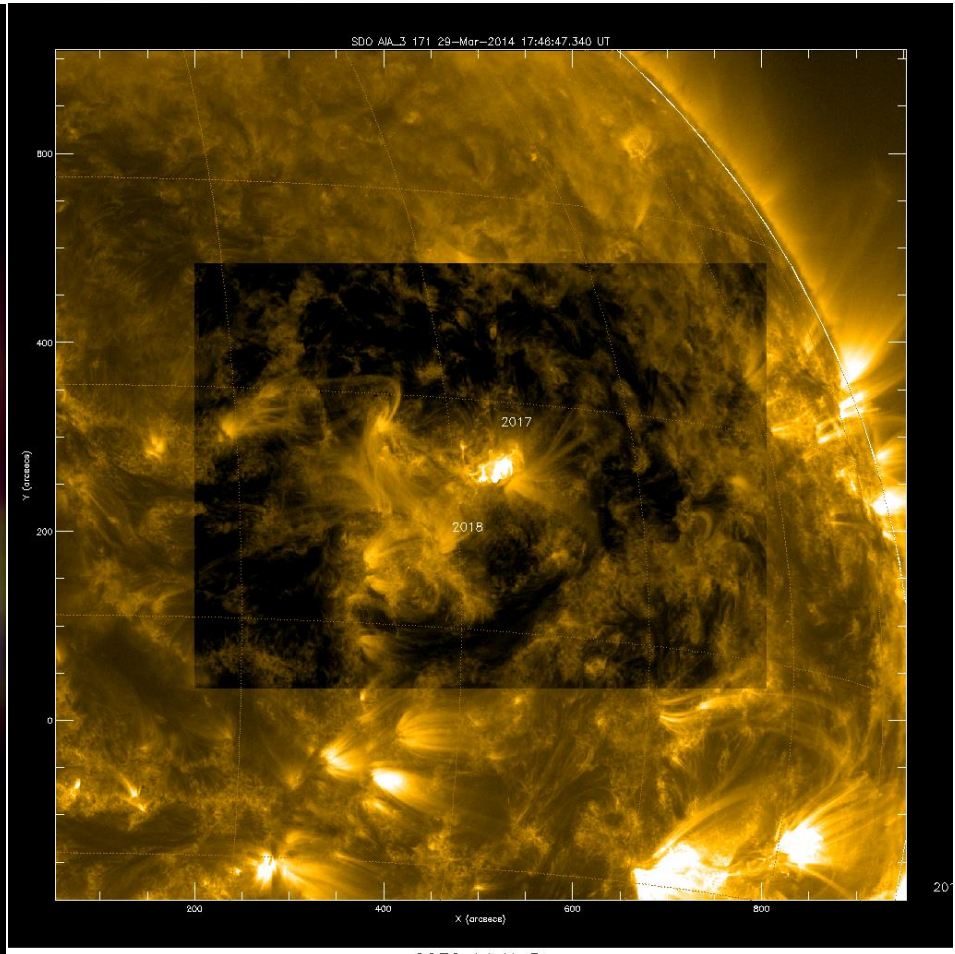
Observations Modeling

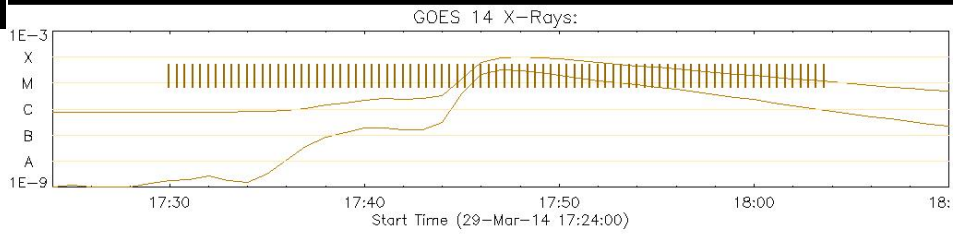


Ukhorskiy et al., In Press at Nature, 2014

X-1 Flare with SDO, HINODE, IRIS, and more!



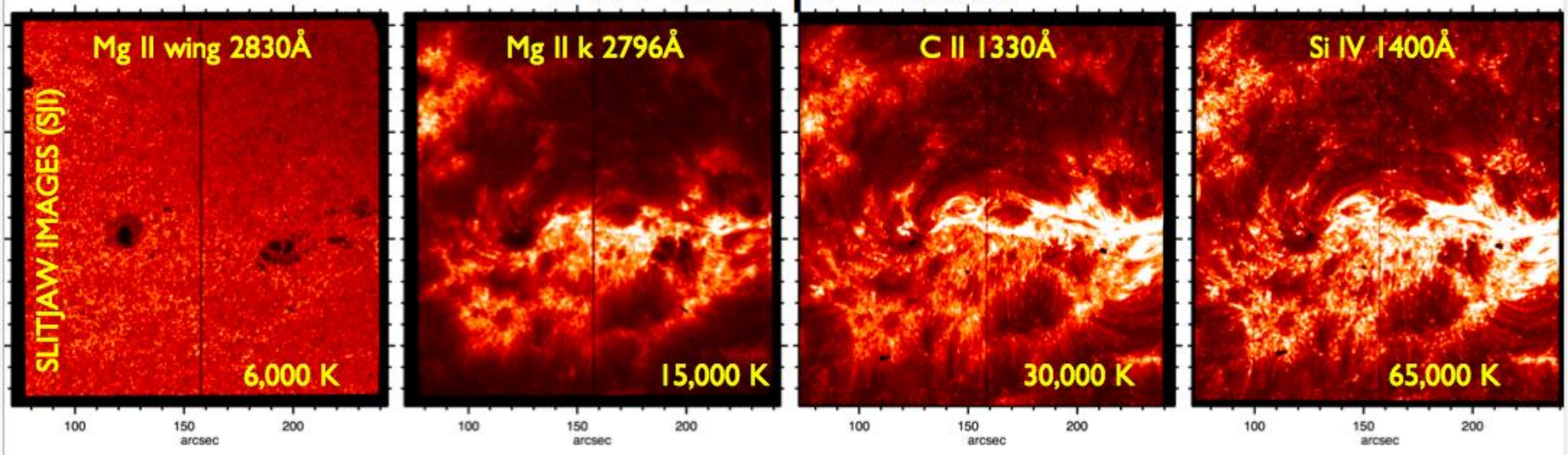




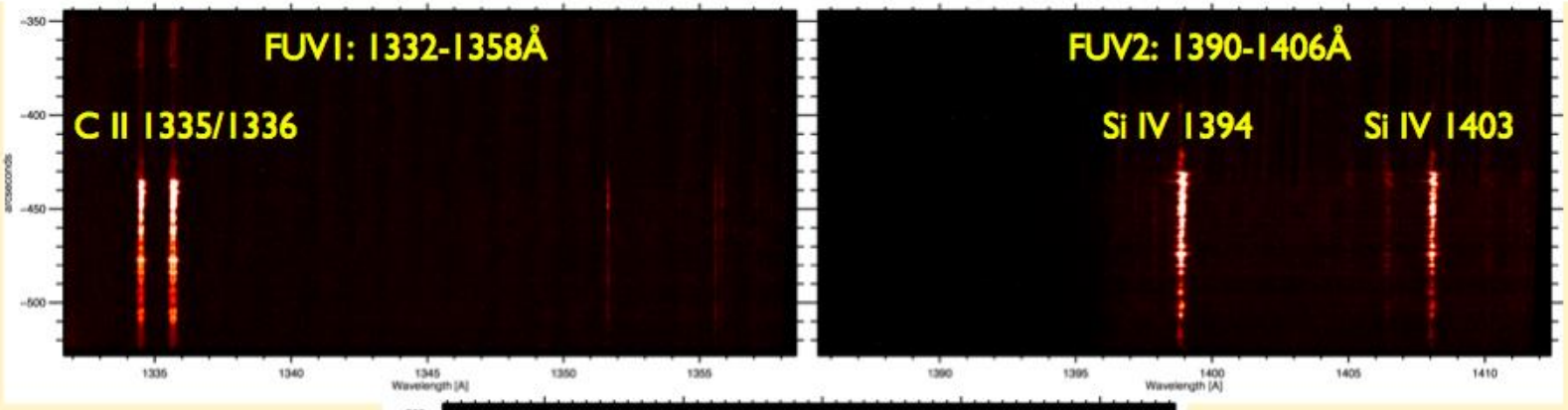
29 March 2014 17:50 UT

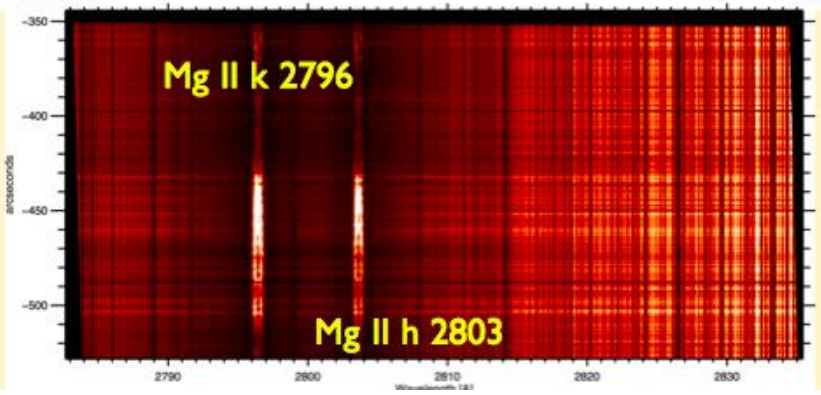
Science data available on the web

IRIS data products

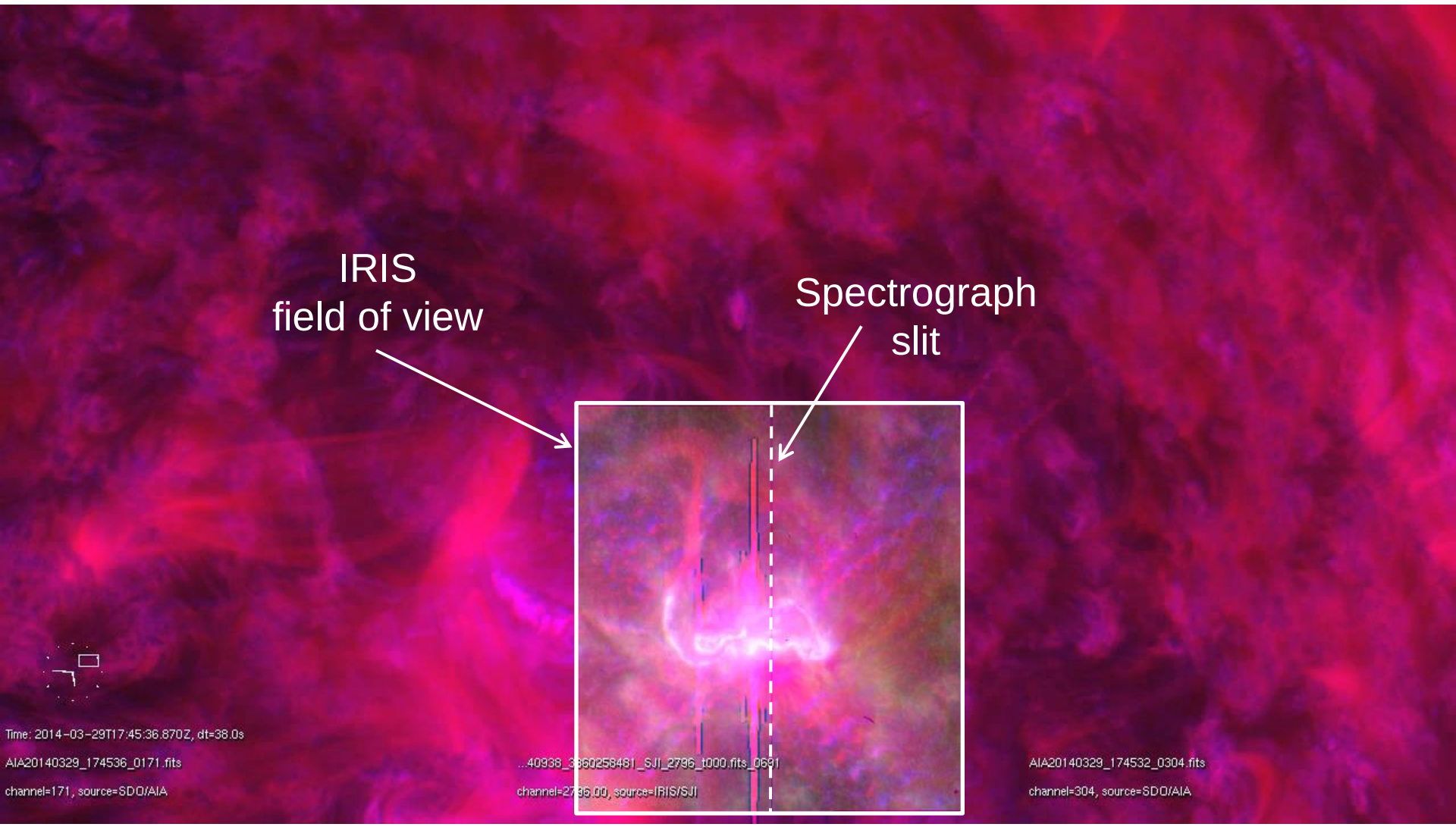


SPECTRA



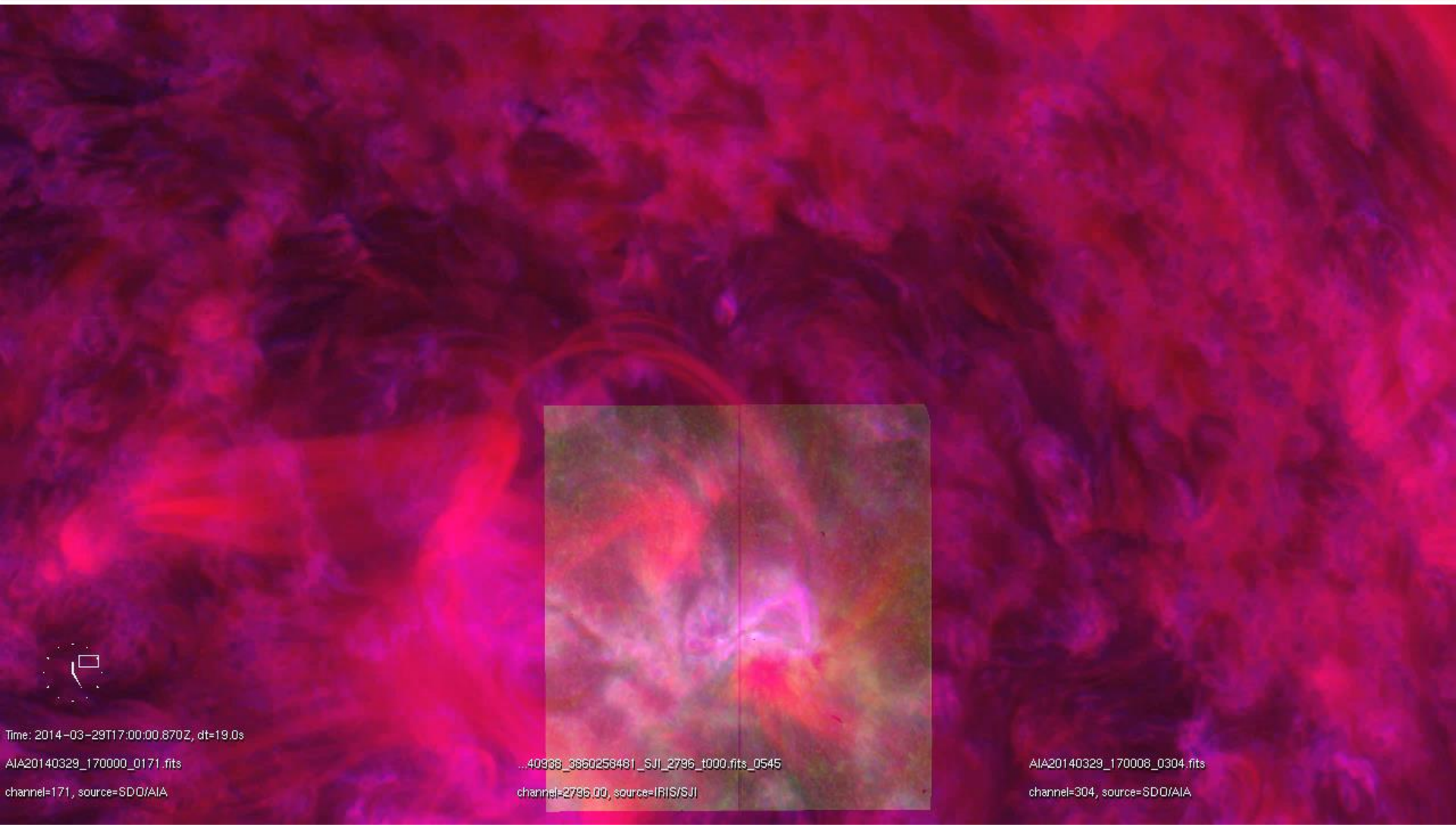


IRIS Observations on AIA Image



Go to “The Sun Today” for 29 March 2014 http://sdowww.lmsal.com/suntoday_v2/

You have to see the movie!



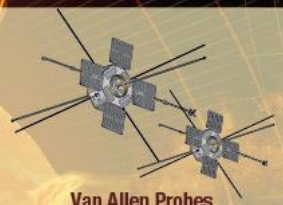
Heliophysics Program 2014-2018

Solar Terrestrial Probes

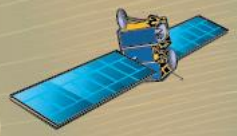
Magnetospheric Multiscale (MMS)
March 2015

STP #5

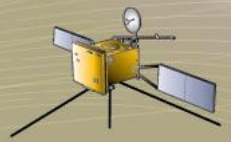
Living With a Star



Van Allen Probes
August 2012



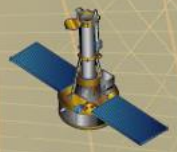
Space Environment Testbeds (SET)
Mid-2016



Solar Orbiter Collaboration (with ESA)
July 2017

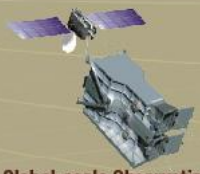
Solar Probe Plus
July 2018

Explorers



Interface Region Imaging Spectrograph (IRIS)
June 2013

Ionospheric Connection Explorer (ICON)
February 2017



Global-scale Observations of the Limb and Disk (GOLD)
September 2017

Research Program

HYPE - May 2014
SubTec Demo - May 2014
CHESS - May 2014
RAISE - June 2014

RockOn Vii- June 2014
VAULT - June 2014
DFS - July 2014
RockSatX- August 2014

MOSES - August 2014
OGRE - October 2014
PEREGRINE#1 - October 2014
PICTURE - October 2014

CAPER - November 2014
C-REX - November 2014
FOXSI - December 2014
Micro-X - December 2014

PEREGRINE#2 - January 2015
ASSP - January 2015
ACCESS - January 2015
CIBER - January 2015

M-TEX - January 2015
PEREGRINE#3 - February 2015
CLASP - August 2015

Ongoing

HySICS - September 2014 / WFF

Heliophysics Missions
Astrophysics Missions
Planetary Missions

2012 2013 2014 2015 2016 2017 2018

NASA's New CubeSat Program

- Heliophysics is administering SMD's new CubeSat budget, $5M/yr in FY14
- Management approach approved at SMD level on 20 February
  - HQ-based administration, "thin" program office supported part-time
  - Modest contribution to support KSC CubeSat Launch Initiative for accommodations
  - CubeSat proposals will be solicited via ROSES and selected by each SMD Division
  - Science CubeSat Integration Panel established
- Science CubeSat Integration Panel responsibilities:
  - Establish policy, incorporate lessons learned, and conduct outreach
  - Integrate management and implementation as needed
  - Recommend awards following review by Divisions
- CubeSat proposals already reviewed are being considered for 2014 awards

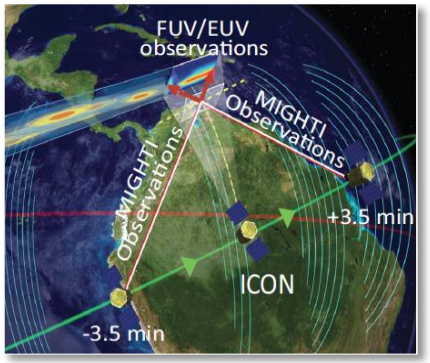
NASA CubeSat proposals will be solicited and selected on the basis of science merit and technology value.

Two New Explorers for Heliophysics

Selected in 2013 for Flight Development, Launch in 2017

ICON

Ionospheric Connection Explorer



- **How neutral atmosphere affects the ionosphere**
- **How solar wind and magnetosphere affect the ionosphere**

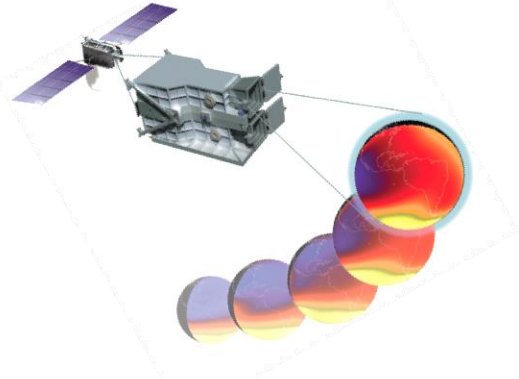
ICON is a single s/c traveling eastward and continuously imaging the thermosphere and ionosphere.

Orbit: 550 km at 24º inclination
PI: **Thomas Immel** / UC Berkeley

- Successful SRR in January 2014
- PDR in July 2014
- Confirmation Review, August 2014

GOLD

Global Scale Observations of the Limb and Disk



… how the ionosphere and thermosphere respond to geomagnetic storms, solar radiation, and upward propagating atmospheric tides

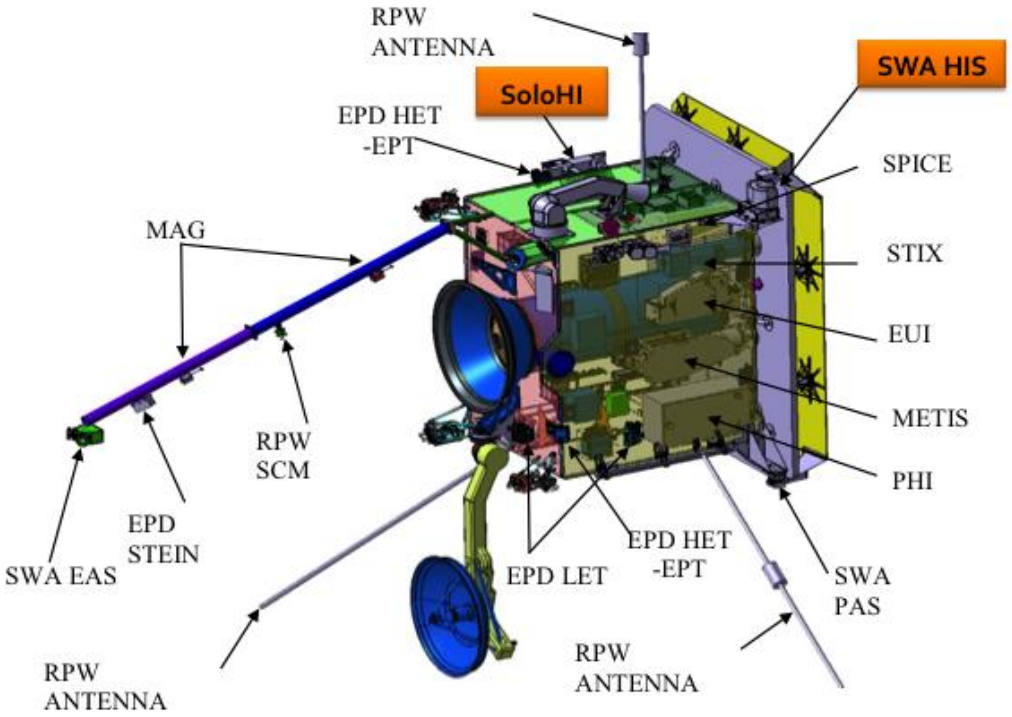
Two identical scanning imaging spectrographs on a geosynchronous commercial communication satellite.

PI: **Richard Eastes** / U. Cent. FL

- Successful SRR in January 2014
- PDR in September 2014
- Confirmation Review in Oct 2014

Solar Orbiter Collaboration (SOC)

Solar Orbiter was selected as the first medium-class mission of ESA's Cosmic Vision 2015-2025 Programme

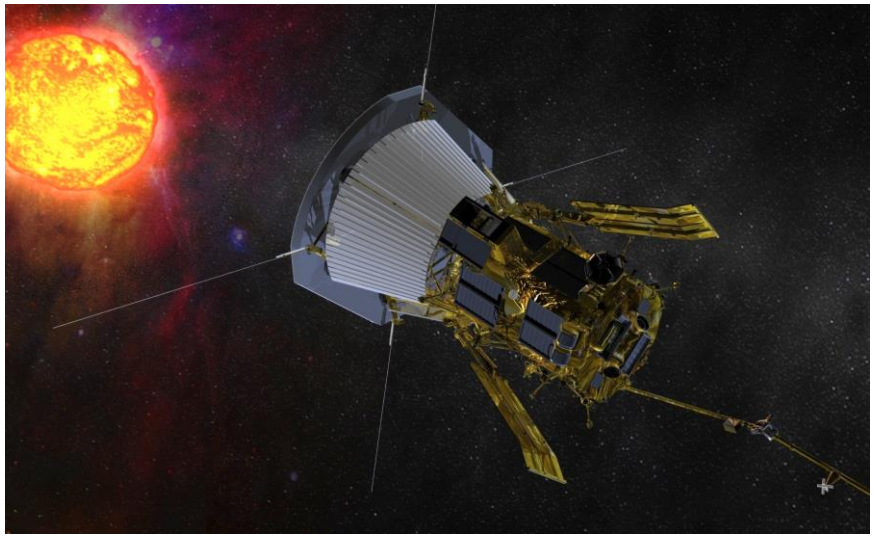


- **Mission design:**
  - Launch: July 2017 (2018 backup)
  - Multiple gravity assist manoeuvres (Venus, Earth)
  - Minimum perihelion: 0.28 AU
  - Out of the ecliptic angle: 25°
  - Maximum solar latitude: 35°
  - Total mission duration: 7 years (plus 3 years of extended phase)

Approved Life cycle cost: $435.9M
NASA launch vehicle in procurement

US-funded instruments SoloHI (NRL) and HIS (SwRI) are preparing for 2015 deliveries to support a July 2017 launch.

Solar Probe Plus (SPP) Confirmed!



- Sponsor: NASA/GSFC Living With a Star (LWS)
- LWS Program Manager – GSFC
- Project Manager – APL
- Project Scientist – APL
- Spacecraft Development & Operations – APL
- Investigations selected by AO:
  - FIELDS – University of California
  - ISIS – Southwest Research Institute
  - SWEAP – Smithsonian Astrophysical Obs
  - WISPR – Naval Research Laboratory
  - HelioOrigins – Jet Propulsion Laboratory

Overview

Using in-situ measurements made closer to the Sun than by any previous spacecraft, SPP will determine the mechanisms that produce the fast and slow solar winds, coronal heating, and the transport of energetic particles.

Solar Probe Plus will fly to less than 10 solar radii (R_s) of the Sun, walking-in from 35 R_s over 24 orbits.

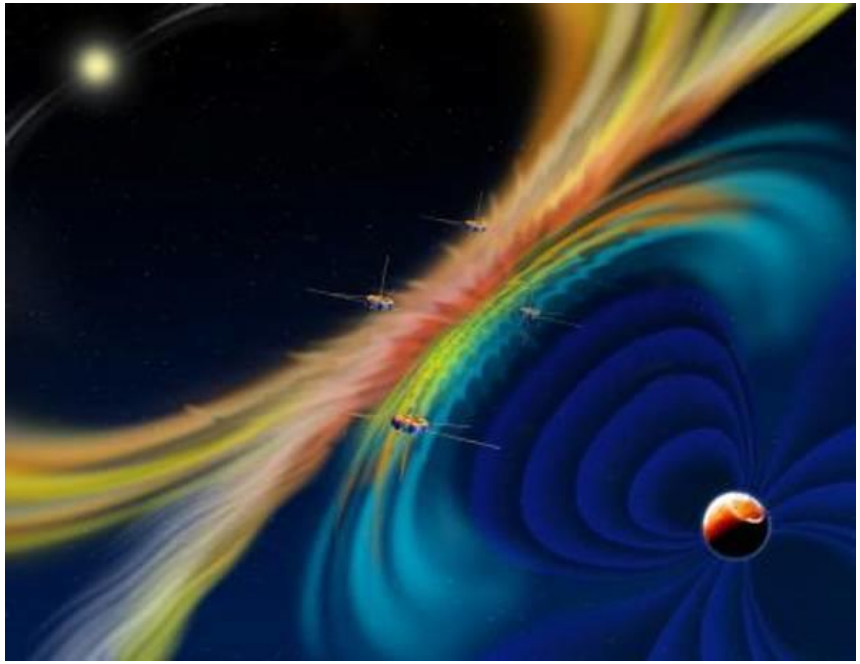
Milestones

✓Pre-Phase A:	07/2008 – 11/2009
✓Phase A:	12/2009 – 01/2012
✓Phase B:	02/2012 – 03/2014
Phase C/D:	03/2014 – 08/2018
LRD:	August 2018
Phase E:	09/2018 – 09/2025

Approved Life cycle cost: $1,553.4M

PDR and Mission Confirmation (KDP-C) Successfully Completed!

Magnetospheric Multi-Scale (MMS)



Science Objective: Investigate the physics of magnetic reconnection, using a constellation of 4 satellites to probe the reconnection region

Partners

- IWF (Austria), LPP (France), ISAS (Japan), KTH (Sweden)
- KSC Launch Services Program for Atlas V

Approved Life cycle cost: $1,081.1M

Instruments

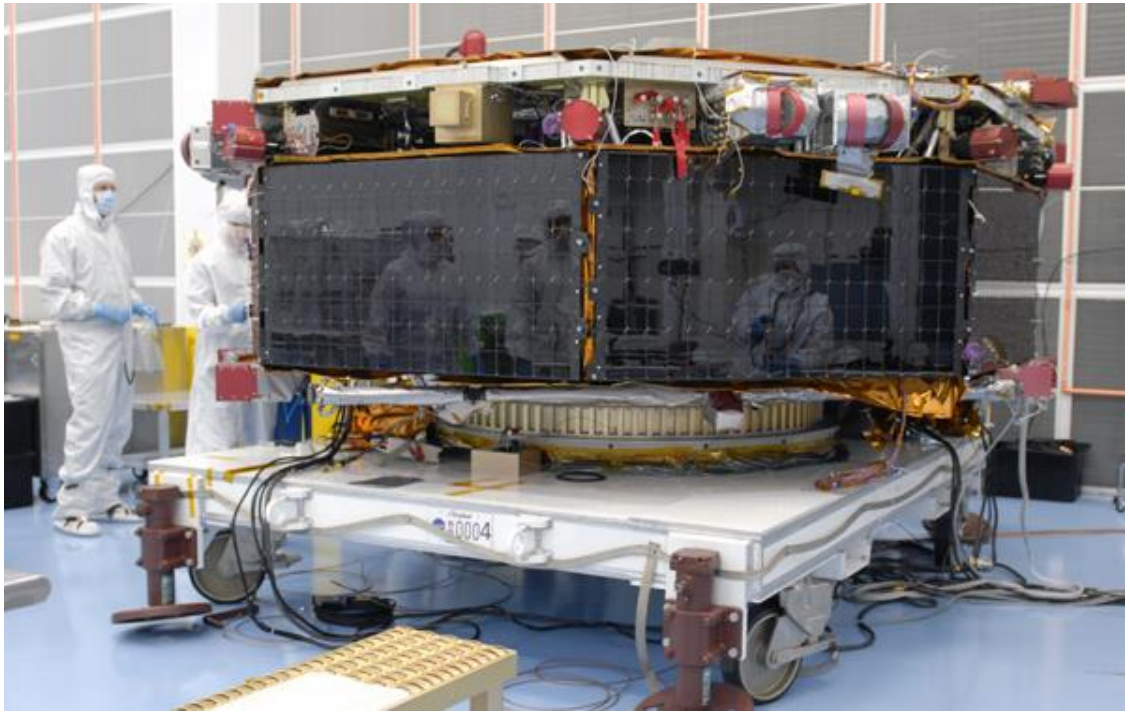
- Instrument Suite: SwRI
  - Fields suite (6 sensor types): UNH, U Colorado, UCLA, IWF, LPP
  - Fast Plasma Investigation (2 sensor types): GSFC, Meisei, SwRI
  - Energetic Particles (2 sensor types): APL, Aerospace
  - Hot Plasma Composition: SwRI
  - ASPOC: IWF

Overall Status

- All 4 satellites are in system-level test
- 3 of 4 completed thermal vacuum test
- Quality issues on one electronic part (HV801)
  - Several instruments affected, all being worked
- Significant cost, schedule impacts of shutdown
- Launch readiness changed from October to 26 November 2014 due to shutdown last fall
- Launch expected in early March 2015

MMS Status and Launch Schedule

Observatory #4 in final assembly



2 of 4 as stacked for launch

Strategic Priorities for the CCMC

1. **Continue to pursue the documented goal of the CCMC:**

   Develop and execute next generation research models in support of the advancement of space sciences and development of new operational space weather capabilities. [expand to "Develop, support, sustain, and execute" ?]

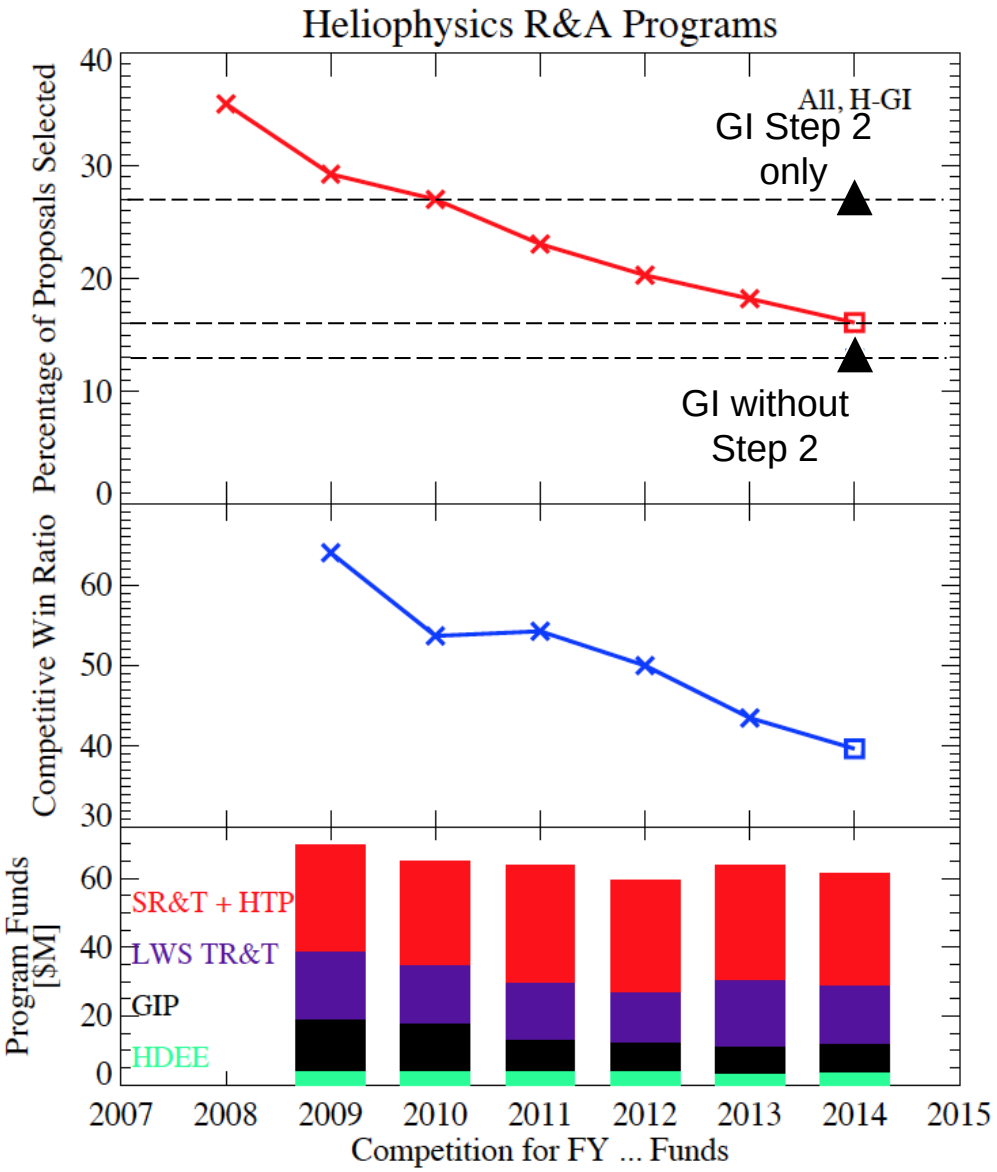
2. **Exploit and apply expertise in model integration and visualization**
   - Integrated Space Weather Analysis System, 3DView, KAMELEON

3. **Expand model validation activities, with focus on operational needs**
   - Coordinate closely with operational agencies to identify needs, plan for the future
   - Continue to maintain and expand on Space Weather Scoreboard
   - Maintain historical database of space weather observations for model validation
   - Support operational agencies with model testing and validation results
   - Lead research required to establish space weather monitoring requirements

CCMC has a unique and significant role in leading the research to better define space weather monitoring requirements.

Issues and Concerns: Research Support

- Community demand for research support is far from satisfied
  - Number of proposals is rising
  - Fraction funded is falling to 1 in 6
  - Several activities and inquiries assessing funding statistics
  - Release of consistent dataset is under way to facilitate discussions
- What are we doing?
  - Expanding the 2-step process
  - “Rebalancing” to increase research fraction of budget per Decadal Survey recommendations
  - Near-term objective: Motivate and justify Decadal Survey recommendation to increase research budget by $10M/year
  - Support the community in explaining the benefits of heliophysics research



Heliophysics Budget and Projections

Budget Authority Dollars	BY(2013)	BY (2014)	BY (2015)	BY+ 1 (2016)	BY+ 2 (2017)	BY+ 3 (2018)	BY+ 4 (2019)
President's Budget Request	**$647.0**	**$643.0**	**$668.9**	**$647.6**	**$676.6**	**$673.3**	**$675.5**
FY13 Sequester Reduction	($30.6)						
FY13 Operating Plan Reductions	($13.9)						
Other adjustments	($0.7)	$10.7					
Total Heliophysics Budget	**$603.2**	**$653.7**	**$668.9**	**$647.6**	**$676.6**	**$673.3**	**$675.5**
Heliophysics Budget Appropriated	**$603.2**	**$654.0**					
Less Admin & Directed R&T*	($16.6)	($44.1)	($55.0)	($12.2)	($16.7)	($18.7)	($19.0)
Net Heliophysics Budget	**$589.7**	**$609.9**	**$613.9**	**$635.4**	**$659.9**	**$654.6**	**$656.5**
Heliophysics Expenditures for FY	**$589.7**						

*These budgets support SMD activities not specific to Heliophysics.

Greyed entries represent notional estimates.

Key Budget Consequences for Heliophysics

- The Heliophysics budget for FY15 is increased over FY14
  - Net of administrative items: $609.8 in FY14, to $613.9 in FY15
- The budget sustains long-standing HPD programs
  - Research & Analysis, operating mission support is essentially constant
- The budget enables a 2018 launch date for Solar Probe Plus without impacting research and analysis support
- It maintains the July 2018 launch date for Solar Orbiter
- It supports MMS through final integration and test
- It funds both ICON and GOLD for launches in 2017

- We will continue to implement the DRIVE initiative
  - Small satellites: CubeSat budget line item is a good start
  - Next objective: $10M/yr increase for MO&DA

Decadal Survey Research Recommendations

Recommendations	Science	Cost
Complete the current Program	Support the existing program elements that constitute the Heliophysics Systems Observatory (HSO) and complete missions in development (RBSP, IRIS, MMS, SOC, SPP).	Review in case of any significant cost growth
DRIVE (Diversify, Realize, Integrate, Venture, Educate)	Strengthen observational, theoretical, modeling, and technical advances with additional R&A capabilities: small satellites; MO&DA funding, science centers and grant programs; instrument development	Program rebalance: move up to $40M/yr into Research
Accelerate and expand Heliophysics Explorer Program	Launch every 2-3 years, alternating SMEX & MIDEX with continuous Missions of Opportunity.	Program rebalance: move$70M/yr into Explorers
Restructure STP line as a moderate scale, PI-led flight program. Implement three mid-scale missions.	Mission 1: Understand the interaction of the outer heliosphere with the interstellar medium; includes L1 space weather observations Mission 2: Understand how space weather is driven by lower atmosphere weather. Mission 3: Understand how the magnetosphere-ionosphere-thermosphere system is coupled and responds to solar forcing.	$520M per mission in FY12$; launches in 2021, 2025, 2029
Start another LWS mission by the end of the decade.	Mission 4: Study the ionosphere-thermosphere-mesosphere system in an integrated fashion.	$1B mission, Launch 2024

Notes: 1) Recommendations listed above are top level, each contains a number of sub-elements
2) Recommendations are listed in priority order, pending budget constraints
3) Recommendations are separable by Agency, only NASA Recommendations are listed here

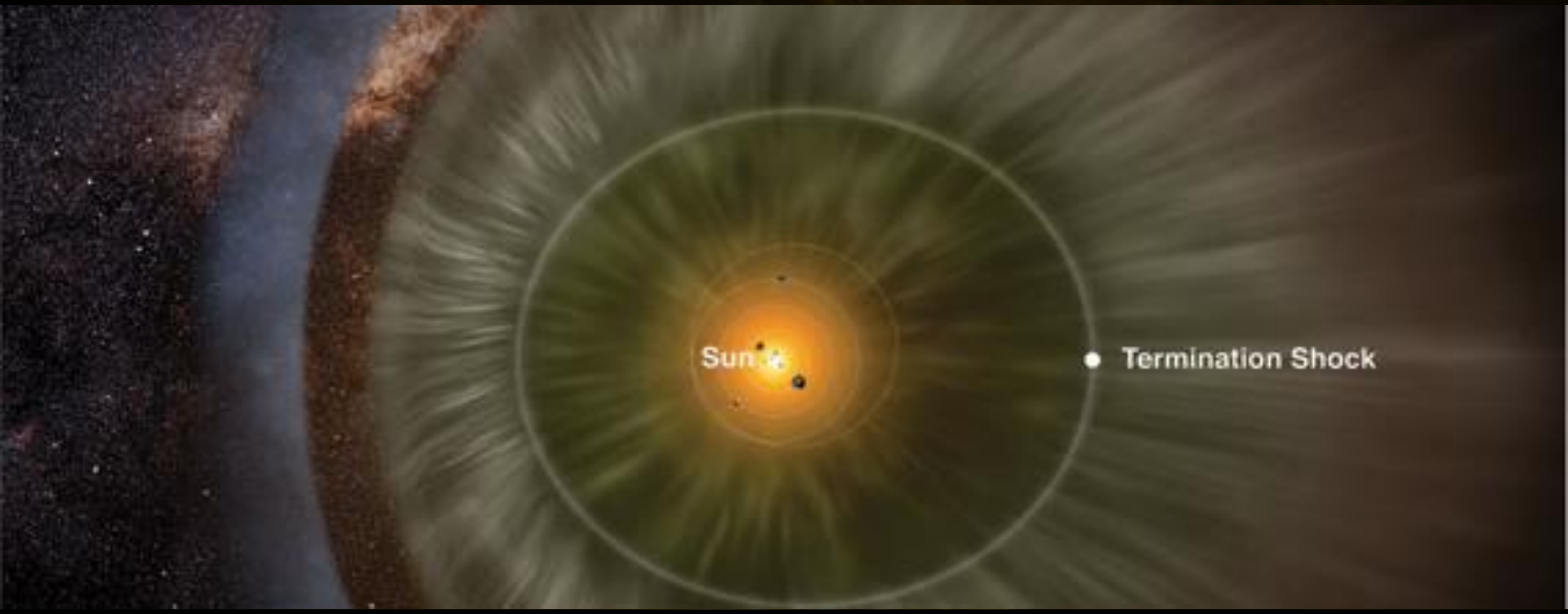
Where is the Heliophysics Division Going?

- **NASA's SMD Heliophysics Division Mission Statement (draft):**
  Adopt the 2013 Heliophysics Decadal Survey and the Roadmap as our foundation to foster the next decade of heliophysics research, and to apply its scientific discoveries to provide direct benefits, both to the science of space weather and, through its study of fundamental processes and coupled systems, to NASA and space science overall.

- **Approach to implementing Decadal Survey recommendations**
  - Heliophysics Roadmap defines our detailed implementation plan for the Decadal Survey, including technology development requirements
  - Perform on our commitments to complete the current program on time and on budget
    - President's FY15 budget supports Solar Probe Plus launch in 2018
  - Strengthen our Research and Analysis, MO&DA, and Technology Programs
    - Work towards rebalancing research program as recommended by the Decadal Survey
  - Plan for more frequent, lower cost missions: Expand Explorers and Missions of Opportunity
    - CubeSat line started in FY14, next Heliophysics Explorer A/O likely in 2016
  - Commence development of the highest priority Strategic Program (STP, LWS) science targets, consistent with the budget and with Research and Explorer priorities

- **Continue to build our understanding of heliophysics (the sun and its interaction with the Earth and the solar system) and the science of space weather**

National Aeronautics and Space Administration



Questions?